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Borrowing Constraint and the Effect of Option Introduction

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Abstract

This paper studies how options trading, by circumventing constraints on borrowing, permits optimistic investors to hold the desired portfolio. Unconstrained investors proceed to a portfolio rebalancing by constructing a zero-income portfolio that consists of a short position in the option, a long position in the stock and a short position in the riskless asset. We show that aggregate demand for the stock is what prevails when options do not exist and no constraints hold. Furthermore, the option listing causes an increase in the aggregate demand for the stock and consequently an increase in the equilibrium stock price.

JEL classification: G11, G13

Keywords: options; credit constraints; stock price; arbitrage

1. Introduction

In the traditional valuation of options the price process of the underlying asset is exogenous. The option price is derived by using an arbitrage argument. In this approach the option is a redundant asset whose payoff can be replicated by portfolios of primary assets. Introducing an option contract has no impact on the price of underlying stock and risk-sharing possibilities are not modified. However, when the assumption of complete and (or) frictionless markets is relaxed, the introduction of an option may affect the price of the underlying asset. In the presence of asymmetric information, the introduction of options affects information revelation through option prices and traders (Grossman (1988), Back (1993), Biais and Hillion (1994)).

Grossman (1988) argues that for an option that can be replicated by dynamic trading strategies, its absence affects the prices of underlying assets due to the informational content of a traded option relative to its synthetic counterpart. If the information is symmetric, the impact of options trading is generally analyzed in the context of incomplete financial markets (Hart (1975), Detemple (1990), Detemple and Selden (1991)). As shown by Detemple and Selden (1991), introducing options may expand opportunities for risk sharing and will in general affect the price of the underlying assets. A usual justification to the creation of options is that they allow the completion of the market (Ross (1976)) and the opening of many sufficient securities allows an efficient allocation of resources. But this argument cannot explain the presence of redundant assets like mutual funds. Financial intermediaries create securities to permit lower transaction costs. Another argument behind financial innovation is the existence of financial restrictions. Generally investors are limited in their ability to short sell assets and in borrowing. Introducing an option may be profitable even if the span of the supplied assets is unaffected by the innovation. The introduction of a redundant option permits constrained investors to circumvent financial restriction and then improve their wealth transfer among different states of nature. This leads to a change of their demand functions on underlying assets and then prices could be modified.

In this paper we analyze the role of a redundant option when some investors are not allowed to borrow at the riskless rate for the purpose of investing in the underlying stock. These investors are optimistic on the chance of the occurrence of the high payoff but are not sufficiently wealthy to hold the quantity of stocks as desired. The introduction of the option permits the achievement of maximum welfare by holding a long position in the option. The presence of unconstrained investors ensures the equilibrium of the option market and the valuation of the option by arbitrage. They sell the option and modify their demand for the stock and for the riskless asset. We show that aggregate demand for stock is what prevails in a financial market without financial constraints and without option trading.

One of the main assumptions in this paper is that investors who provide liquidity to the option market are not subject to wealth constraints. Gârleanu et al. (2009) assume that market makers take the other side of the net demand of private investors. They cannot hedge their option positions perfectly but they do not face financial constraints. Santa-Clara and Saretto (2009) show that, due to margin requirements and limited access to capital, non-market makers are restricted when

seeking to write S&P500 options. This leads them to the conclusion that investors do not compete with market makers for supplying liquidity to the option market.

The rest of the paper is organized as follows: Section 2 describes the model. Section 3 analyzes the impact of introducing a redundant option. The effect of modification the fraction of constrained investors on the stock price is studied in Section 4. Section 5 concludes.

2. The model

We consider a single good and an exchange economy with one period (two dates, zero and one). The financial market is composed of three assets: a stock in fixed supply, a call option written on the stock which is in zero net supply and a riskless asset in perfectly elastic supply at a price of one and yielding a rate of return equal to zero. The prices of the stock and the option are respectively p_s and p_o . We denote by p_s^* the equilibrium stock price in the absence of the option market and p_s^{**} in the case of option trading. We denote \tilde{v} the stock payoff, $\tilde{g} = \text{Max}(\tilde{v} - k, 0)$ the payoff of the option and k the exercise price. We normalize the supply of stocks to be one unit. Investors have prior beliefs regarding the distribution of the stock payoff. The formation of expectations is exogenous to the model.

In our model, investors are competitive and form a continuum with measure 1. These investors are either borrowing constrained or unconstrained. Investors of the first type ($i = 1$), in fraction N , have unlimited access to credit. Investors of the second type ($i = 2$), in fraction $1 - N$, cannot rely on borrowing to buy stocks. At $t = 0$ investors determine their portfolio. At $t = 1$ the uncertainty resolves and investors consume. Let x_s^i and x_o^i represent respectively the shares holding of the stock and option, $W^i(0)$ the first date wealth and $W^i(1)$ the final date wealth of investor i . Let U_1 and U_2 be the utility of an investor of the first type and second type respectively, and which are strictly increasing and strictly concave. We assume $W^1(0) \geq W^2(0)$, that is investors who are subject to the borrowing constraint do not have more initial wealth than unconstrained investors.

3. The effect of option introducing

Investors generally use credit or margin to increase their purchasing power so that they can own more stocks without fully paying for it. They borrow money from their broker to buy a stock and use the investment as collateral. According to US regulation, investors may borrow up to 50 percent of the purchase price of securities that can be purchased on margin. Even if investors use the margin system frequently, they are restricted in their ability to rely on this possibility. In this section we analyze the possibilities of trading created by the introduction of a redundant option in the presence of a borrowing constraint. We consider an extreme situation, where some investors, who form the second type, are not allowed to borrow but investors from the first type are unconstrained. Many authors have studied the case of agents having different ability to borrow at the riskless rate for the purpose of investing in risky assets. In Kiyotaki and Moore (1997), farmers are credit constrained whereas Gathers are unconstrained. In Yuan (2005), a fraction of informed investors face borrowing

constraints. In Detemple and Serrat (2003), some agents are subject to liquidity constraints in that the value of their portfolios must be nonnegative at all times. Unconstrained agents, however, can trade the stock and the riskless asset without restriction and then use their labor income as collateral for an aggregate short position. As in our framework, markets are complete from their point of view.

In this section we assume that the stock payoff can take only two possible values v_H and v_L where $(0 < v_L < v_H)$ and $(v_L < k < v_H)$. There are several criteria to characterize a complete financial market. In the absence of imperfections, these criteria are equivalent. The financial market is said to be complete if the number of non-redundant assets is equal to the number of successor states. In a second definition, a financial market is complete whenever investors can transfer as much wealth as desired among different states. In our context and because of the borrowing constraint, these two criteria are not equivalent when the option is not traded. In fact, a constrained investor cannot construct the first Arrow asset, with payoff $(1, 0)$. To see this, suppose the contrary. Then we would have x_S and x_B verifying $x_B(1, 1) + x_S(v_H, v_L) = (1, 0)$, which leads to $x_B = -x_S v_L$ and $x_S = 1/(v_H - v_L)$. Hence $x_S > 0$ and $x_B < 0$, a contradiction to the borrowing constraint. The creation of the option leads to the completion of the market by the two criteria. The first Arrow asset is formed by purchasing $1/(v_H - k)$ options. Also with a long position of $1/v_L$ stocks and a short position of $v_H/v_L(v_H - k)$ options one can construct the second Arrow asset. We then adopt the second definition and consequently the financial market is incomplete when the option is not traded. We say that it is more complete when the fraction of unconstrained investors increases.

For unconstrained investors the option contract is redundant. The condition of no-arbitrage opportunity requires that $v_L < p_S < v_H$ and

$$\begin{cases} p_0 = \omega_1 + \omega_2 p_S \\ \tilde{g} = \omega_1 + \omega_2 \tilde{v} \end{cases} \quad (1)$$

where $\omega_1 = -(v_H - k)v_L/(v_H - v_L) < 0$, $\omega_2 = (v_H - k)/(v_H - v_L) > 0$.

3.1. Without the option market

The wealth $W^i(0)$ allows investor i to invest $p_S x_S^i$ in the stock and $W^i(0) - p_S x_S^i$ in the riskless asset. His time 1 wealth is given by $\tilde{W}_1^i = W_0^i + x_S^i(\tilde{v} - p_S)$. Each investor chooses his portfolio at date zero so as to maximize expected utility of date one wealth. Let $\Gamma_i(x_S^i) = E_i U_i(W^i(0) + x_S^i(\tilde{v} - p_S))$. In the absence of the borrowing constraint, the demand for the stock of investor i , denoted by X_S^i , is solution of equation $\Gamma_i'(x_S^i) = 0$. The quantity X_S^i verifies

$$E_i[(\tilde{v} - p_S)U_i'(W^i(0) + X_S^i(\tilde{v} - p_S))] = 0 \quad (2)$$

Investor of type 1 is unconstrained; his demand function for the stock is given by $X_s^1(\cdot)$. For the investor of type 2, her demand function for the stock is the solution of the program:

$$\begin{cases} \text{Max} E_2 U_2(\tilde{W}^2(1)) \\ p_s x_s^2 \leq W^2(0) \end{cases}$$

For a given stock price, if $X_s^2 \leq W^2(0) / p_s$, her demand for the stock is X_s^i but if $X_s^2 > W^2(0) / p_s$ she does not hold the riskless asset and then invests all her wealth in the stock. The borrowing would allow reaching a superior expected utility compared to the case when all her wealth is invested in the risky asset. A Constrained investor, who is optimistic about the chance of the stock appreciation, would invest more in the stock if she were allowed to borrow.

We are interested in the situation where the borrowing constraint imposed on investors of type 2 is binding¹.

Assumption 1 We restrict the set of parameters describing the economy such that, with and without options, $X_s^2 > W^2(0) / p_s$ in equilibrium. This assumption indicates that constrained investors are optimistic about the stock payoff.

3.2. With the option market

The date-1 wealth of each investor is given by:

$$\tilde{W}_1^i = W^i(0) + x_s^i(\tilde{v} - p_s) + x_0^i(\tilde{g} - p_0)$$

By (1) we have:

$$\tilde{W}_1^i = W^i(0) + (x_s^i + \omega_2 x_0^i)(\tilde{v} - p_s) \quad (3)$$

For the unconstrained investor the option is redundant. Its introduction has no impact on his expected utility (for the same stock price). His optimal demands for the stock and option verify:

$$x_s^1 + \omega_2 x_0^1 = X_s^1 \quad (4)$$

The introduction of the option induces a change of his demand for the stock so that $x_s^1 + \omega_2 x_0^1$ corresponds to his demand for the stock when options are not traded. We show below that in equilibrium he holds a short position in the option ($x_0^1 < 0$) and then $x_s^1 > X_s^1$; this investor sells $|x_0^1|$ options and buys a quantity of stocks superior to what happens if the option does not exist.

For investor 2 the program is to maximize her expected utility with the constraint that $p_s x_s^2 + p_0 x_0^2 \leq W_0^2$.

$$\text{Max} E_2 U_2(W^2(0) + x_s^2(\tilde{v} - p_s) + x_0^2(\tilde{g} - p_0))$$

¹We could assume that for a fraction of constrained investors the borrowing constraint is not binding in equilibrium. However, this framework does not change the results of this paper.

$$p_s x_s^2 + p_0 x_0^2 \leq W^2(0)$$

The existence of the option contract, other things equal, allows her to increase expected utility of date-1 wealth. The first order conditions are:

$$\begin{cases} E_2[(\tilde{v} - p_s)U'_2(\tilde{W}^2(1))] - \lambda p_s = 0 \\ E_2[\omega_2(\tilde{v} - p_s)U'_2(\tilde{W}^2(1))] - \lambda p_0 = 0 \\ \lambda(W^2(0) - p_s x_s^2 - p_0 x_0^2) = 0, \lambda \geq 0 \end{cases}$$

The first two equations imply that $\lambda \omega_2 p_s = \lambda p_0$. From (1) it comes that $\lambda = 0$. Hence $E_2[(\tilde{v} - p_s)U'_2(\tilde{W}^2(1))] = 0$. Consequently, we obtain the following equation:

$$x_s^2 + \omega_2 x_0^2 = X_s^2 \quad (5)$$

From equations (3) and (5) we can state the following Proposition.

Proposition 1 The option introduction permits constrained investors to circumvent imperfections in that their expected utility is what will be attained if constraints are nonexistent.

The condition of clearing on the option market is $Nx_0^1 + (1 - N)x_0^2 = 0$. From (4) and (5) we deduce that the aggregate demand for the stock when the option is traded is $NX_s^1 + (1 - N)X_s^2$. Then

Proposition 2 When the option market is introduced, the aggregate demand for the stock is the same as when the option market does not exist and there are no portfolio constraints.

This result, consistent with the finding of Stein (1987), permits to conclude to a relation between opening a derivative market and the aggregate demand for the underlying asset. The introduction of the option permits constrained investors to choose their holdings of risky assets so that their wealth constraint is respected and expected utility is at maximum. The option contract allows constrained investors to circumvent market imperfections.

When options do not exist the clearing of the stock market yields

$$NX_s^1(p_s^*) + (1 - N)W^2(0) / p_s^* = 1 \quad (6)$$

In the presence of the option market, the stock market-clearing condition is

$$NX_s^1(p_s^{**}) + (1 - N)X_s^2(p_s^{**}) = 1 \quad (7)$$

Proposition 3 In equilibrium and under assumption 1, constrained investors hold a long position in the option.

Proof: Using (1) and (5) we have

$$p_s x_s^2 + p_0 x_0^2 = p_s X_s^2 + \omega_1 x_0^2$$

The budget constraint yields

$$x_0^2 \geq (W^2(0) - p_s X_s^2) / \omega_1 \quad (8)$$

The result follows from the assumption that $p_s X_s^2 > W^2(0)$ in equilibrium.

In equilibrium, a constrained investor holds a long position in the option such that (8) is verified and completes her portfolio by a quantity of stocks that satisfies equation (5). She has an infinite number of possibilities for the composition of her optimal portfolio, which lead to the same equilibrium prices for the stock and option. As an example she could not hold the riskless asset so the quantities of stocks and options in her portfolio are such that $x_s^2 + \omega_2 x_0^2 = X_s^2$ and $p_s x_s^2 + p_0 x_0^2 = W^2(0)$. Even if investors of the first type do not share the optimism of investors of the second type, they sell them the option and then demand an additional quantity of the stock to put a perfect hedge of their position on the option market.

If the stock price was unchanged, the creation of the option market increases the expected utility of constrained investors but do not modify the expected utility of unconstrained investors. As we show later, when the option is created, the aggregate demand for the stock is modified and then the equilibrium stock price changes.

We consider a second restriction on the parameters of the economy.

Assumption 2 The demand functions $X_s^1(\cdot)$ and $X_s^2(\cdot)$ are strictly decreasing in the stock price.

This hypothesis guarantees, among others things, that the equilibrium stock price is unique.

Let us examine the derivative dX_s^i / dp_s for the arbitrary utility function in order to determine sufficient conditions that make Assumption 2 hold. Differentiating (2) with respect to stock price we get:

$$\frac{dX_s^i}{dp_s} = \frac{E_i[U_i'(\tilde{W}^i(1))] + X_s^i E_i[(\tilde{v} - p_s)U_i''(\tilde{W}^i(1))]}{E_i[(\tilde{v} - p_s)^2 U_i''(\tilde{W}^i(1))]}$$

Let $R_A(\cdot) = -U_i''(\cdot)/U_i'(\cdot)$ denote the absolute risk aversion. The sign of $E_i[(\tilde{v} - p_s)U_i''(\tilde{W}^i(1))]$ depends on the sign of $dR_A(z)/dz$ (Huang and Litzenberger (1988) page 22). Under a strictly decreasing absolute risk aversion, that is when $dR_A(z)/dz < 0$, $E_i[(\tilde{v} - p_s)U_i''(\tilde{W}^i(1))]$ has the sign of X_s^i and hence assumption 2 is verified. The same result holds in the case of a utility function of class CARA since $E_i[(\tilde{v} - p_s)U_i''(\tilde{W}^i(1))] = 0$. In contrast, when $dR_A(z)/dz$ is strictly positive then $E_i[(\tilde{v} - p_s)U_i''(\tilde{W}^i(1))]$ and X_s^i have different signs and consequently the sign of dX_s^i / dp_s is ambiguous. Assumption 2 also holds for preferences of mean-variance type.

We can now establish the following result on the effect of introducing an option market on the stock price.

Proposition 4 Under assumptions 1 and 2, introducing an option contract increases the equilibrium stock price.

Proof: Let us suppose that $p_s^{**} \leq p_s^*$. It follows from assumption 2 that $X_s^1(p_s^{**}) \geq X_s^1(p_s^*)$. Since p_s^* and p_s^{**} verify respectively (7) and (8), then $X_s^2(p_s^{**}) \leq W^2(0) / p_s^*$. Hence $X_s^2(p_s^*) \leq W^2(0) / p_s^*$, is a contradiction to assumption 1.

The same result is derived by Detemple and Selden (1991) who study the case of an option contract that does not complete the financial market and investors have diverse beliefs about the risk of the stock payoff. The empirical findings of Conrad (1989) confirm the price effect of the option introduction and support our analysis of investors' behavior. He analyzes 96 options listed between 1974 and 1980 and shows that the price effect begins three to four days before the option introduction. Also the price increase is positively related to opening day trading volume in the option. These two facts lead Conrad to conclude that some traders are buying securities for hedging purposes in anticipation of the trading volume in the option. Grossman (1988) has shown that the introduction of an option that can be synthesized by existing assets can have an impact on the price of the underlying asset due to the informational content of the traded option. In our framework no asymmetric information holds, however, as Proposition 4 states, the introduction of a redundant option may affect the stock price because of the impossibility of borrowing imposed on some optimistic agents.

Example Let $U_i(z) = -\exp(-\beta_i z)$ with $\beta_i > 0$ for $i = 1, 2$. The utility functions U_1 and U_2 are strictly increasing and are strictly concave. Since they are of class CARA then the demand functions $X_s^1(\cdot)$ and $X_s^2(\cdot)$ are strictly decreasing in the stock price. We deduce that option listing induces an increase in the price of the underlying asset for families of preferences in the CARA class.

The option listing also modifies the holdings of the riskless asset. When options are not traded, only unconstrained investors hold the riskless asset. When options are traded, each unconstrained investor holds two portfolios; the portfolio held in the absence of the option market and a zero-income portfolio. The latter portfolio consists of a short position in the option with a quantity of x_0^1 , a long position in the stock in quantity $-w_2 x_0^1$ and a short position in the riskless asset, in quantity $-w_1 x_0^1$. We verify easily that this portfolio is a zero-income portfolio since $-w_2 x_0^1 p_s + x_0^1 p_0 - x_0^1 w_1 = 0$ and $-w_2 x_0^1 \tilde{v} + x_0^1 \tilde{g} - x_0^1 w_1 = 0$. Since the supply of the stock is unchanged and $p_s^{**} > p_s^*$, it follows that the options trading induces a decrease in the aggregate holdings of the riskless asset.

4. Modification of the fraction of constrained investors

This section considers the case in which there are only a stock and a riskless asset and we assume that the stock payoff takes an arbitrary distribution function. We analyze the impact of a change of the fraction of unconstrained investors on the equilibrium stock price. When N changes, the aggregate demand function for the stock is modified and then the equilibrium stock price varies. Let us assume that, in

equilibrium, demand X_s^1 of unconstrained investors is not smaller than the unconstrained demand X_s^2 of constrained investors.

Assumption 3 $X_s^1 \geq X_s^2$ in equilibrium.

Next, we derive sufficient conditions for assumption 3 to hold. In the special case where the utility function of investors is exponential and the stock payoff can take only two possible values v_H and v_L ($0 < v_L < v_H$), we have

$$X_s^i = \frac{1}{\beta_i(v_H - v_L)} \log - \frac{\gamma_i(v_H - p_s)}{(1 - \gamma_i)(v_L - p_s)} \quad (9)$$

where β_i denotes the risk aversion and γ_i the belief about the probability of the high payoff v_H ($0 < \gamma_i < 1$) of agent i . We say that agent i becomes more optimistic if γ_i increases. If $\beta_1 = \beta_2$ we show easily that the demand function of unconstrained investor $X_s^1(\cdot)$ is higher than the demand function of constrained investor $X_s^2(\cdot)$ when $\gamma_1 > \gamma_2$ and the two functions are equal when $\gamma_1 = \gamma_2$. In the case where investors have the identical perception of the probability of states of nature ($\gamma_1 = \gamma_2$), they share the same expected return on the stock. By Assumption 1, the investment in the stock by the constrained investor is strictly positive. Consequently his expectation on expected return is strictly positive and it is the same for investor of type 1. We deduce from (9) that assumption 3 holds when unconstrained investors are not more risk averse ($\beta_1 \geq \beta_2$). Let us finally examine the case where the two types of investors have arbitrary but identical utility and they agree on the probabilities they assign to stock payoffs. The unconstrained demand functions for the stock $X_s^1(\cdot)$ and $X_s^2(\cdot)$ may be different only if $W^1(0)$ and $W^2(0)$ are different. Recall that if the investment on the stock is positive, then it is an increasing function of initial wealth when absolute risk aversion is strictly decreasing in wealth (Huang and Litzenberger (1988) page 21). By assumption 1 and since expectation on expected return are common to both types of investors, then demands X_s^1 and X_s^2 are positive in equilibrium. Consequently, assumption 3 holds in the case of decreasing risk aversion.

The effect of varying the fraction of constrained investors is summarized as follows.

Proposition 5 Under assumptions 1, 2 and 3, the equilibrium stock price increases with the fraction of unconstrained investors.

Proof: Using (6) and differentiate with respect to N we get:

$$\frac{dp_s}{dN} \left[N \frac{dX_s^1}{dp_s} - (1 - N) \frac{W^2(0)}{(p_s^*)^2} \right] = \frac{W^2(0)}{p_s^*} - X_s^1$$

It follows from Assumption 2 that $dX_s^1 / dp_s < 0$. Assumptions 1 and 3 imply that $W^2(0) / p_s^* < X_s^2 \leq X_s^1$. Hence $dp_s / dN > 0$.

That is because increasing the fraction of first type investors act as if some constrained investors, who invest initially all their endowment in the stock, increase their holding of the stock as they now belong to the first type. Since we assume that the demand of unconstrained investor is superior to the demand of constrained investor, then the aggregate demand for the stock increases which induces an increase in the equilibrium stock price.

Let us consider the case where the only heterogeneity between the two types of investors concerns the possibility to borrow. In this case, their wealth, utility function and subjective probabilities of successor states are identical. It then follows that unconstrained demand functions $X_s^1(.)$ and $X_s^2(.)$ are identical. We denote these demands by $X_s(.)$. From (6) and (7), the following proposition is immediate.

Proposition 6 The equilibrium stock price in the presence of the option is equal to the stock price when options do not exist and N converges to 1.

From the results of Propositions 5 and 6, it follows that the price effect of introducing an option depends on the importance of the two types and it is relatively small when most investors are unconstrained (N is close to one). The fraction N could be seen as a determinant of completion degree of the market. It follows that the price effect of the option listing decreases when the market is becoming more complete. The theoretical results of Detemple and Jorion (1988) are similar. They consider two risky assets and two investors with different but constant relative risk aversion. For certain values of parameters, the price of the first risky asset increases when an option on that asset is traded. This price effect lasts but becomes relatively small when an option on the second asset is introduced. Detemple and Jorion (1990) examine the impact of option listing in the period 1973-1986. They remark that price increase and volatility decrease are dissipated after 1982. A possible interpretation of our previous result and the empirical finding of Detemple and Jorion (1990) suggest that, as the market becomes nearly complete, the price effect becomes insignificant in the period 1983-1986.

5. Conclusion

In this paper we demonstrate that in a financial market with borrowing constraints the introduction of an option that leaves the span unaltered induces changes in the demands for the underlying stock and hence the equilibrium stock price may change. We considered two types of investors who differ in their ability to borrow at the riskless rate. The introduction of the option permits each investor to transfer wealth as desired among different states. Investors of the second type, who are optimistic about the chance of the stock appreciation but are not allowed to borrow, hold a long position in the option. Unconstrained investors, who form the first type of investors, supply the option and then modify their demand for the stock. We show that the aggregate demand for the stock is what prevails in a financial market without options and without constraints. The option introduction has the same impact on equilibrium allocations and stock price as abandoning financial imperfection. Under the condition that demands for the stock are decreasing in the stock price, the introduction of the option increases the equilibrium stock price.

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